

Recommendations for ICHx/AC'97 Audio

Motherboard and Communication and Network Riser

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1. Introduction

Intel's first generation integrated AC'97 Controller (referred to here as ICH) was designed to support 2 Codecs – one Audio Codec and one Modem Codec. Intel's second generation integrated AC'97 Controller (referred to here as ICH2) maintains dual Codec support but adds multichannel (2,4 6) audio and Sony/Philips Digital Interface S/PDIF* output capability. Intel originally envisioned a single monolithic Audio Codec providing all audio functionality, with motherboard audio as the predominant implementation, and limited use of riser cards as vehicles for enhancing Original Equipment Manufacturer (OEM) configurability. Following this vision, motherboards with audio populated would not be upgradeable; and motherboards without audio would offer 2, 4, or 6 channel audio with or without S/PDIF via riser (or PCI) add-in card audio.

With the advent of the new Communications and Networking Riser (CNR), with Plug-and-Play (PnP) functionality, it becomes feasible to consider motherboard audio augmented by a second Codec on a riser – enabling the potential for point-of-sale OEM motherboard audio functionality upgrades via addition of a riser card. However, as its name implies, CNR supports emerging communications and networking technologies in addition to audio.

With the attach rate for audio approaching 100%, but that of modems, xDSL, LAN, and HPNA differing widely by segment and geography, over dependence on CNR audio (vs. motherboard audio) could become a hindrance rather than an asset.

In addition, enabling robust, easy to configure motherboard plus riser audio upgrades is a complex undertaking with many interdependencies such as Controller and Codec implementation, Audio Codec configuration, BIOS detection and configuration, CNR implementation, as well as audio driver support. Testing, validation, and certification are also intensive, time-consuming activities.

Motherboard plus CNR audio upgrade scenarios have a large number of market and technical complexities that demand careful consideration – at this time, cross-vendor Codec compatibility should not be expected.

1.1 Purpose of this white paper

This white paper will discuss Intel's recommendations for the role of ICHx/AC'97 audio, CNR audio, and selected motherboard plus CNR audio configurations.

The specific goals are to:

- Identify Intel recommended motherboard and CNR audio configurations that maximize the potential of ICH and ICH2.
- Clearly communicate to Codec, motherboard, BIOS, CNR, and Driver developers which audio configurations Intel intends to recommend in future generations of ICHx.

2. AC'97 Codec types

The following is an enumeration of possible Audio Codec types, which will be referred to throughout this discussion. (The type numbers are arbitrarily assigned for Codec configuration identification purposes only, and do not correspond to any bit fields in the AC'97 or CNR specifications).

Type	Function	AC '97 Slot #'s			
		3&4	7&8	6&9	10&11**
00	2-ch Primary	L&R	-	-	-
01	2-ch Primary with S/PDIF	L&R	S/PDIF	-	-
02	4-ch Primary	L&R	Rear	-	-
03	4-ch Primary with S/PDIF	L&R	Rear	S/PDIF	-
04	6-ch Primary	L&R	Rear	C/LFE	-
05	6-ch Primary with S/PDIF	L&R	Rear	C/LFE	S/PDIF
06	+2-ch Rear	-	Rear	-	-
07	+2-ch Rear with S/PDIF	-	Rear	S/PDIF	-
08	+4-ch Rear/Center/LFE	-	Rear	C/LFE	-
09	+4-ch Rear/Center/LFE with S/PDIF	-	Rear	C/LFE	S/PDIF
10	+2-ch Center/LFE	-	-	C/LFE	-
11	+2-ch Center/LFE with S/PDIF	-	-	C/LFE	S/PDIF
** Slots 10&11 were originally allocated to modem line 2 and handset, but are available when no Modem Codec is used (or when a combo Audio/Modem Codec does not support line 2 and handset). Dedicated support for S/PDIF on slots 10&11 is not supported by the ICH and ICH2 – all S/PDIF compliant Codecs must accept S/PDIF data on slots 3&4, 7&8, or 6&9. Note: Currently, the infrastructure for 6-channel analog audio (content, OS, speakers, etc.) is very limited.					

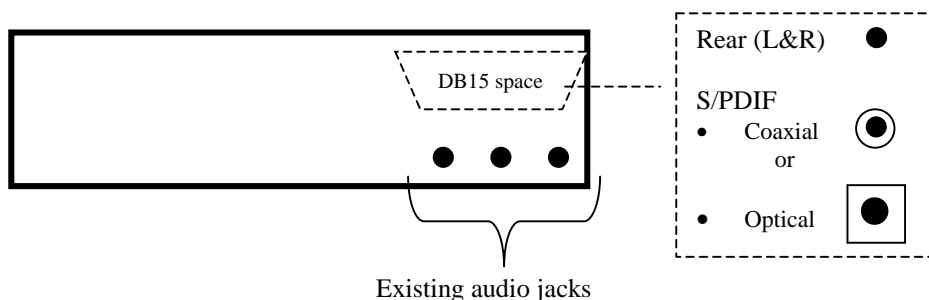
3. Recommendations for motherboard audio

Motherboard audio offers many possibilities for high quality, low Bill Of Materials (BOM) cost audio implementations, and frees up use of CNR for emerging communications and networking technologies such as modem, Digital Subscriber Line (DSL), Local Area Network (LAN), and Home Phone Networking Alliance (HPNA).

Intel recommends the following motherboard audio solutions (highlighted in **bold** in the tables below):

1. **“Basic” motherboard audio**: 2-channel (upgradeable via CNR, see section 5 below)
2. **“Deluxe” motherboard audio**: 4-channel (vendor specific CNR upgrade feasible, but not very compelling)
3. **“Audiophile” motherboard audio**: 2- or 4-channel with S/PDIF (not upgradeable via CNR)

In order to support motherboard 4-channel and/or S/PDIF, Intel suggests a revised back panel connector that eliminates the stacked DB15 gameport/MIDI connector and replaces it with added stereo mini jacks for Rear channel output and coaxial or optical S/PDIF.



3.1 Intel ICH support for motherboard audio

Intel's ICH supports 2 channel audio with S/PDIF, for Codec types 00-01 configured as Primary (Codec ID 00) on the motherboard. Intel specifically recommends the audio solutions highlighted in **bold** for ICH.

Intel ICH support for motherboard AC'97 audio			
Type	Function	Codec ID	AC '97 Slot #'s
			3&4
00	2-ch Primary	00	L&R
01**	2-ch Primary with S/PDIF	00	L&R, S/PDIF

** Type 01 Codec implementations have S/PDIF concurrency limitations. Dedicated support for S/PDIF is not supported by ICH – all S/PDIF compliant Codecs must accept S/PDIF data on slots 3&4.

3.2 Intel ICH2 support for motherboard audio

Intel's ICH2 supports 2, 4, or 6 channel audio with concurrent S/PDIF, for Codec types 00-05 configured as Primary (Codec ID 00) on the motherboard. Intel specifically recommends the audio solutions highlighted in **bold** for ICH2.

Intel ICH2 support for motherboard AC'97 audio					
Type	Function	Codec ID	AC '97 Slot #'s		
			3&4	7&8	6&9
00	2-ch Primary	00	L&R	-	-
01	2-ch Primary with S/PDIF	00	L&R	S/PDIF	-
02	4-ch Primary	00	L&R	Rear	-
03	4-ch Primary with S/PDIF	00	L&R	Rear	S/PDIF
04	6-ch Primary	00	L&R	Rear	C/LFE
05**	6-ch Primary with S/PDIF	00	L&R, S/PDIF	Rear	C/LFE, S/PDIF

** Type 05 Codec implementations have S/PDIF concurrency limitations. Dedicated support for S/PDIF on slots 10&11 is not supported by the ICH2 – all S/PDIF compliant Codecs must accept S/PDIF data on slots 3&4, 7&8, or 6&9.

Note: Currently, the infrastructure for 6-channel analog audio (content, apps, OS, speakers) is limited.

4. Recommendations for Primary CNR audio

CNR audio enhances flexibility for configurations where no audio resides on the motherboard. However, note that Primary CNR audio functionality competes for CNR slot availability with emerging communications and networking technologies, such as modem, DSL, LAN, and HPNA.

Intel recommends the following Primary CNR audio solutions (highlighted in **bold** in the tables below).

1. **“Basic” CNR audio:** Primary 2-channel audio for value systems
2. **“Audiophile” CNR audio:** Primary 2- or 4-channel audio Codec with S/PDIF, high quality Digital to Analog Converters (DACs), and gold connectors

It takes significant effort to develop, test, and certify CNR audio products. While 2,4,6 channel with or without S/PDIF is supported (as shown in the tables below), the two solutions recommended above enable OEMs with the full range of audio scalability – from low end (Baseline) to high end value-add (Audiophile).

4.1 Intel ICH support for Primary CNR audio

Intel's ICH supports 2 channel audio with S/PDIF, for Codec types 00-01 configured as Primary (Codec ID 00) on a CNR. Intel specifically recommends the audio solutions highlighted in **bold** for ICH.

Intel ICH support for Primary CNR AC'97 audio			
Type	Function	Codec ID	AC '97 Slot #'s
			3&4
00	2-ch Primary	00	L&R
01**	2-ch Primary with S/PDIF	00	L&R, S/PDIF
** Type 01 Codec implementations have S/PDIF concurrency limitations. Dedicated S/PDIF is not supported by ICH – all S/PDIF compliant Codecs must accept S/PDIF data on slots 3&4.			

4.2 Intel ICH2 support for ICH2 Primary CNR audio

Intel's ICH2 supports 2, 4, or 6 channel audio with concurrent S/PDIF, for Codec types 00-05 configured as Primary (Codec ID 00) on a CNR. Intel specifically recommends the audio solutions highlighted in **bold** for ICH2.

Intel ICH2 support for Primary CNR AC'97 audio					
Type	Function	Codec ID	AC '97 Slot #'s		
			3&4	7&8	6&9
00	2-ch Primary	00	L&R	-	-
01	2-ch Primary with S/PDIF	00	L&R	S/PDIF	-
02	4-ch Primary	00	L&R	Rear	-
03	4-ch Primary with S/PDIF	00	L&R	Rear	S/PDIF
04	6-ch Primary	00	L&R	Rear	C/LFE
05**	6-ch Primary with S/PDIF	00	L&R, S/PDIF	Rear	C/LFE, S/PDIF
** Type 05 Codec implementations have S/PDIF concurrency limitations. Dedicated support for S/PDIF on slots 10&11 is not supported by the ICH2 – all S/PDIF compliant Codecs must accept S/PDIF data on slots 3&4, 7&8, or 6&9.					
<i>Note: Currently, the infrastructure for 6-channel analog audio (content, apps, OS, speakers) is limited.</i>					

5. Guidelines for motherboard plus Secondary CNR audio upgrades

The most compelling audio upgrade takes a stereo system (i.e. 2-channel only) and adds multichannel capability – support for Rear channels (4-speaker output) *and* S/PDIF output (digital AC-3* 5.1 export). However, note that CNR audio upgrade functionality competes for CNR slot availability with emerging communications and networking technologies, such as modem, DSL, LAN, and HPNA.

Intel recommends just one motherboard plus CNR audio upgrade solution for mainstream desktop PCs (highlighted in **bold** in the tables below).

1. **“Basic to audiophile” 2-channel on motherboard +2 Rear with S/PDIF on CNR:** Add Secondary 2-channel audio Codec with S/PDIF.

Intel's current recommendation for motherboard plus CNR audio upgrades is that the same Codec vendor provides both motherboard Codec and riser Codec. The OEM and the system integrators should insure that both the motherboard and the CNR Codecs are of the same family from a single vendor.

As mentioned earlier, although technically feasible, motherboard plus Secondary CNR audio upgrade scenarios have a number of market and technical complexities that limit their applicability and demand careful consideration. Enabling robust, easy to configure motherboard plus riser audio upgrades is a complex undertaking with many interdependencies, including:

- multiple generations of Controller and Codec implementations from multiple vendors
- a large number of potential Audio Codec configurations
- BIOS detection and configuration
- CNR implementation
- audio driver must comprehend multichannel upgradeability.
- industry expectations for proper labeling and identification of jacks and connectors
- hardware and driver interdependency and certification bottlenecks (i.e. BIOS, Codec, CNR, WHQL)
- competition for CNR slot availability with modem, DSL, LAN, and HPNA

For these reasons, Intel does NOT recommend the following motherboard plus CNR audio upgrade scenarios:

1. Replacement of (disabled) Primary motherboard audio with Primary CNR audio – shipping **non-functional** audio jacks presents significant ease of use issues¹.
2. Upgrade (Secondary) CNR audio with input jacks – shipping **redundant** audio jacks presents significant ease of use issues¹.
3. Upgrade of S/PDIF enabled Primary Motherboard configurations – these systems are considered complete solutions (i.e. fully Dolby* Digital compatible) offering stereo, 4-channel matrix surround, and S/PDIF 5.1 digital output options.
4. “Add S/PDIF only” upgrades.

¹ Note: The circuitry described in the ICH2 Design Guide describes a solution that allows for disabling primary 2-ch Codecs down on the motherboard when a CNR with audio Codec(s) is plugged in (specifically a 4- or 6-channel Primary audio CNR). However, for the reasons cited above, Intel is not recommending this for mainstream desktop PCs. Intel also believes that 6-channels of analog audio output is an undesirable solution compared to 2- or 4-channel analog with Dolby Digital* (AC-3 compatible) 5.1 channel output capability utilizing S/PDIF as described in this white paper.

5.1 Guidelines for ICH motherboard plus Secondary CNR audio upgrade

ICH motherboard audio is not upgradeable via CNR – i.e. motherboards with audio populated are not upgradeable.

However, as stated earlier, in ICH systems CNR can still be used as a vehicle for enhancing OEM configurability – ICH motherboards without audio can offer various flavors (2 channel with or without S/PDIF) of CNR audio.

5.2 Guidelines for ICH2 motherboard plus Secondary CNR audio upgrade

In addition to ICH2 motherboards without audio offering various flavors (2,4,6 channel with or without S/PDIF) of CNR audio, ICH2 systems support the following motherboard plus CNR audio upgrades.

Intel guidelines for ICH2 audio upgradeability only recommend support for motherboard configurations based on Codec Type 00. (Vendor specific support for other motherboard configurations may be feasible.)

ICH2 CNR audio upgradeability requires the upgrade Codec on the CNR be assigned Codec ID 01, which is not compliant with AC'97 2.1 AMAP recommendations for multiple audio Codec functionality. This means that ICH2 compatible CNR upgrade audio Codec addressing and AC-link Slot assignments utilize vendor specific mapping capabilities.

Intel's current recommendation for motherboard plus CNR audio upgrades is that the same Codec vendor provides both motherboard Codec and riser Codec.

The following are Intel's guidelines for ICH2 based motherboard plus CNR audio upgrade configurations:

Upgradeable motherboard configuration					
Type	Function	Codec ID	AC '97 Slot #'s		
			3&4	7&8	6&9
00	2-ch Primary	00	L&R	-	-

Upgrade CNR configurations					
Type	Function	Codec ID	AC '97 Slot #'s		
			3&4	7&8	6&9
06	+2-ch Rear	01	-	Rear	-
07	+2-ch Rear with S/PDIF	01	-	Rear	S/PDIF
08	+4-ch Rear/Center/LFE	01	-	Rear	C/LFE
09**	+4-ch Rear/Center/LFE with S/PDIF	01	-	Rear	C/LFE, S/PDIF

** Type 09 Codec implementations have S/PDIF concurrency limitations. Dedicated support for S/PDIF on slots 10&11 is not supported by ICH2 – all S/PDIF compliant Codecs must accept S/PDIF data on slots 3&4, 7&8, or 6&9.

Note: Currently, the infrastructure for 6-channel analog audio (content, apps, OS, speakers) is limited.

5.3 Guidelines for future ICHx motherboard plus Secondary CNR audio upgrade

Non-functional or redundant audio jacks and unlabeled connectors do not meet the industry's current ease of use connector and jack labeling standards for mainstream desktop PCs. A "Universal audio CNR" re-configurable as either Primary audio or Secondary upgrade audio is therefore discouraged. Secondary CNR audio must be able to convey to the BIOS and audio driver its specific intended function – and this must match what is labeled on the audio jacks and connectors. AC'97 specifies the use of Codec ID as a method for determining Codec function.

As discussed previously, ICH2 compatible CNR upgrade audio Codec addressing and AC-link Slot assignments currently utilize vendor specific mapping capabilities. Intel's current recommendation for motherboard plus CNR audio upgrades is that the same Codec vendor provides both motherboard Codec and riser Codec. It is not practical to re-engineer BIOS and Driver detection and configuration for each new vendor specific implementation – a common solution needs to be developed for next generation Controllers and Codecs.

Intel is evaluating support for AC '97's recommended *AC-link Slot-to-DAC Mappings* (aka AMAP) for default Codec configuration in next generation AC'97 Controllers and CNR products. These proposed changes would make it possible to use the currently defined (AC '97 2.1 compliant) AMAP defaults with CNR upgrades (specifically Codec IDs 10 and 11) on future generations of ICHx. Under evaluation are:

- AMAP compliant addressing for next generation Audio Controllers – i.e. give ICHx the capability to address Secondary Codec ID's 10 and 11, in addition to 01.
- Enhancing CNR's BIOS based Codec detection algorithm to support non-sequential Codec IDs on SDATA_INx lines in multiple Codec systems.

However, since a precedent for non AMAP compliant scenarios has been established, Intel is therefore *strongly recommending* that ALL future Codecs which are designed to be configurable as Secondary for upgrade purposes, *whether AMAP compliant or not*, adopt the following power up AC-link to DAC mapping behavior:

A Secondary audio Codec by default always assigns its DACs to AC-link slots in a fixed sequence {L, R, LR, RR, C, LFE to 3, 4, 7, 8, 6, 9} with the Codec ID dictating where in the sequence to begin (see table below). Default S/PDIF assignment always begins with the first slots not assigned to DACs. Vendor specific remapping capability is also recommended.

Default AC-link to DAC mapping by Codec ID						
Type	Function	Codec ID	3&4	7&8	6&9	10&11
00	2-ch Primary	00	L&R	–	–	–
06**	+2-ch Secondary	01	–	Rear	–	–
06	+2-ch Secondary	10	–	Rear	–	–
10	+2-ch Secondary	11	–	–	C/LFE	–
01	2-ch Primary with S/PDIF	00	L&R	S/PDIF	–	–
07**	+2-ch Secondary with S/PDIF	01	–	Rear	S/PDIF	–
07	+2-ch Secondary with S/PDIF	10	–	Rear	S/PDIF	–
11	+2-ch Secondary with S/PDIF	11	–	–	C/LFE	S/PDIF
02	4-ch Primary	00	L&R	Rear	–	–
08**	+4-ch Secondary	01	–	Rear	C/LFE	–
08	+4-ch Secondary	10	–	Rear	C/LFE	–
03	4-ch Primary with S/PDIF	00	L&R	Rear	S/PDIF	–
09**	+4-ch Secondary with S/PDIF	01	–	Rear	C/LFE	S/PDIF
09	+4-ch Secondary with S/PDIF	10	–	Rear	C/LFE	S/PDIF
** These new defaults for a Secondary Codec configured as ID 01 override the original AMAP recommendations for docking Codec functionality from AC'97 2.1. Since docking is by nature proprietary, the vendor specific support can be used to reconfigure Codec 01 if necessary. The rest of the mappings are compatible with the original AMAP.						

The following are Intel's guidelines for CNR audio upgrade on future generations of ICHx:

Upgradeable motherboard configuration					
Type	Function	Codec ID	AC '97 Slot #'s		
			3&4	7&8	6&9
00	2-ch Primary	00	L&R	-	-

Upgrade CNR configurations					
Type	Function	Codec ID	AC '97 Slot #'s		
			3&4	7&8	6&9
06	+2-ch Rear	01	-	Rear	-
07	+2-ch Rear with S/PDIF	01	-	Rear	S/PDIF
08	+4-ch Rear/Center/LFE	01	-	Rear	C/LFE
09**	+4-ch Rear/Center/LFE with S/PDIF	01	-	Rear	C/LFE, S/PDIF
** Type 09 Codec implementations have S/PDIF concurrency limitations. Dedicated support for S/PDIF on slots 10&11 is not supported by ICH2 – all S/PDIF compliant Codecs must accept S/PDIF data on slots 3&4, 7&8, or 6&9. <i>Note: Currently, the infrastructure for 6-channel analog audio (content, apps, OS, speakers) is limited.</i>					

5.4 Cross-vendor support for motherboard plus Secondary CNR audio upgrade

Intel's current recommendation for motherboard plus CNR audio upgrades is that the same Codec vendor provides both motherboard Codec and riser Codec.

Standardized support for future *cross-vendor multiple Codec multichannel audio upgrades* would require faithful adherence to some very fine details of Codec implementation, many of which are not currently specified in the AC'97 specification.

The following is a list of potential compatibility issues:

- synchronization
- slot request behavior, especially start and stop
- queue depth
- SRC mechanism
- slot mapping configuration
- chaining mechanism
- internal gain
- phase inversions